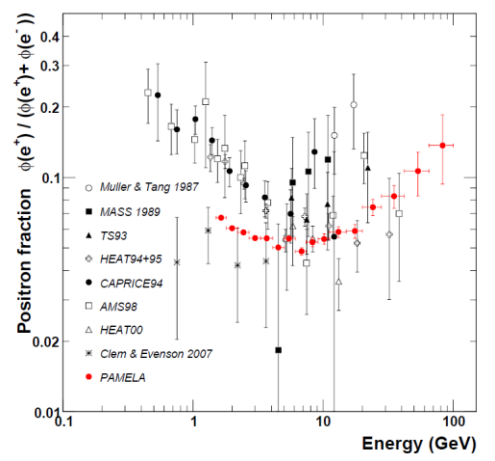
NEUTRINO SIGNATURES OF DARK MATTER

Neutrinos & Dark Matter
Madison, WI
Aug. 31-Sep, 4, 2009

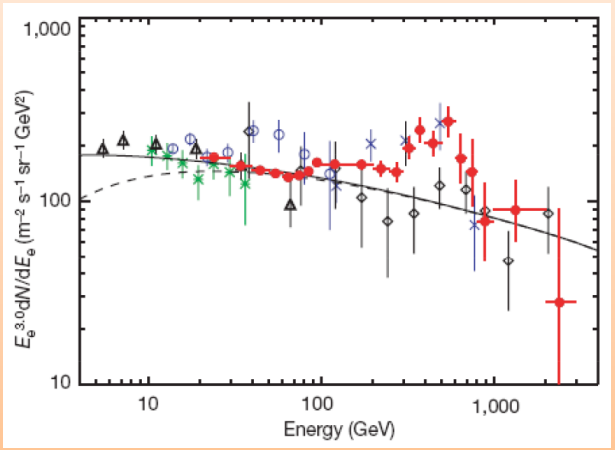
Hasan Yüksel
Bartol Research Institute
University Of Delaware

Primary Sources: e^- accelerated in supernova remnants
Secondary Sources: $e^\pm$ from collisions between cosmic rays & ISM protons

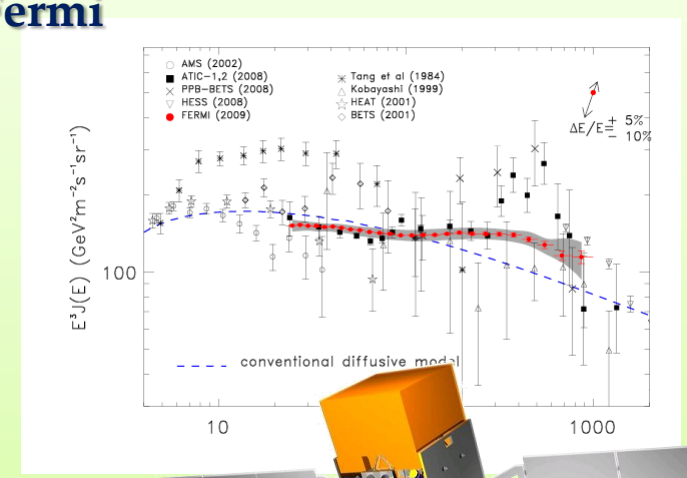
PAMELA

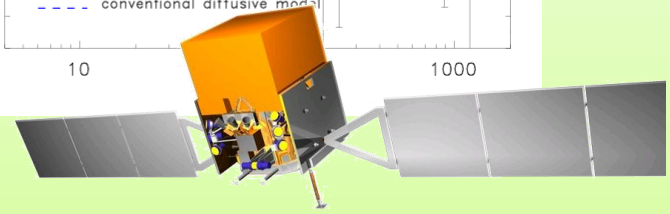


ATIC

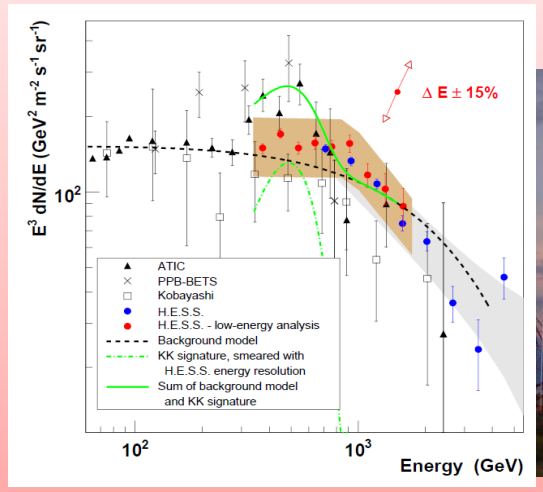


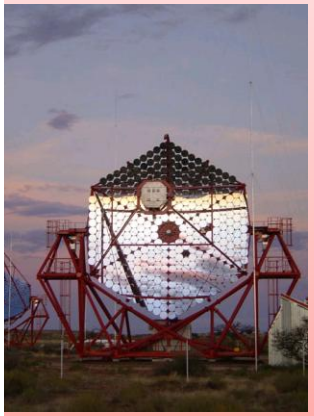
Fermi





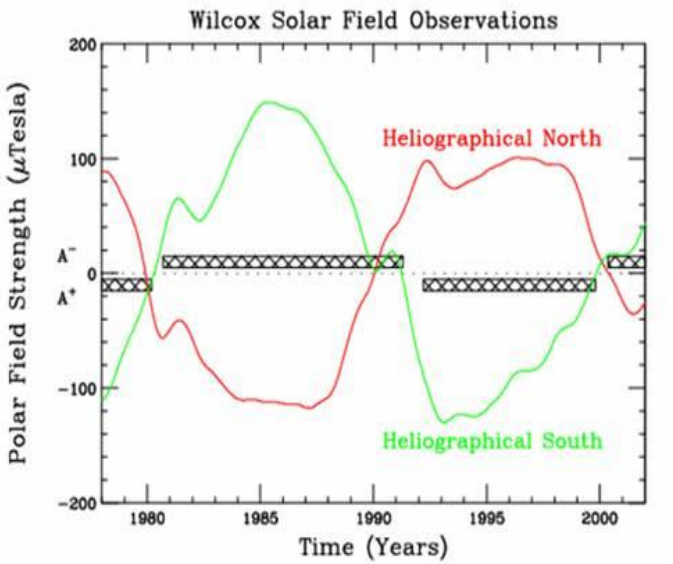
Hess

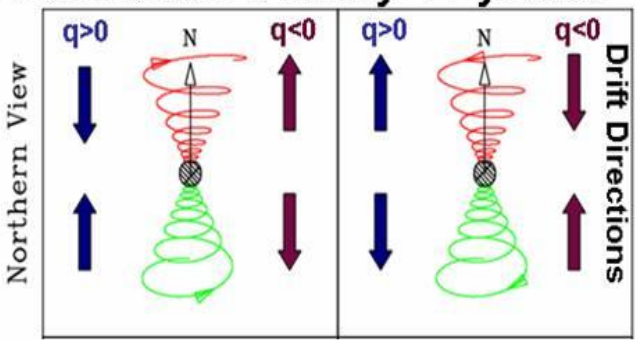




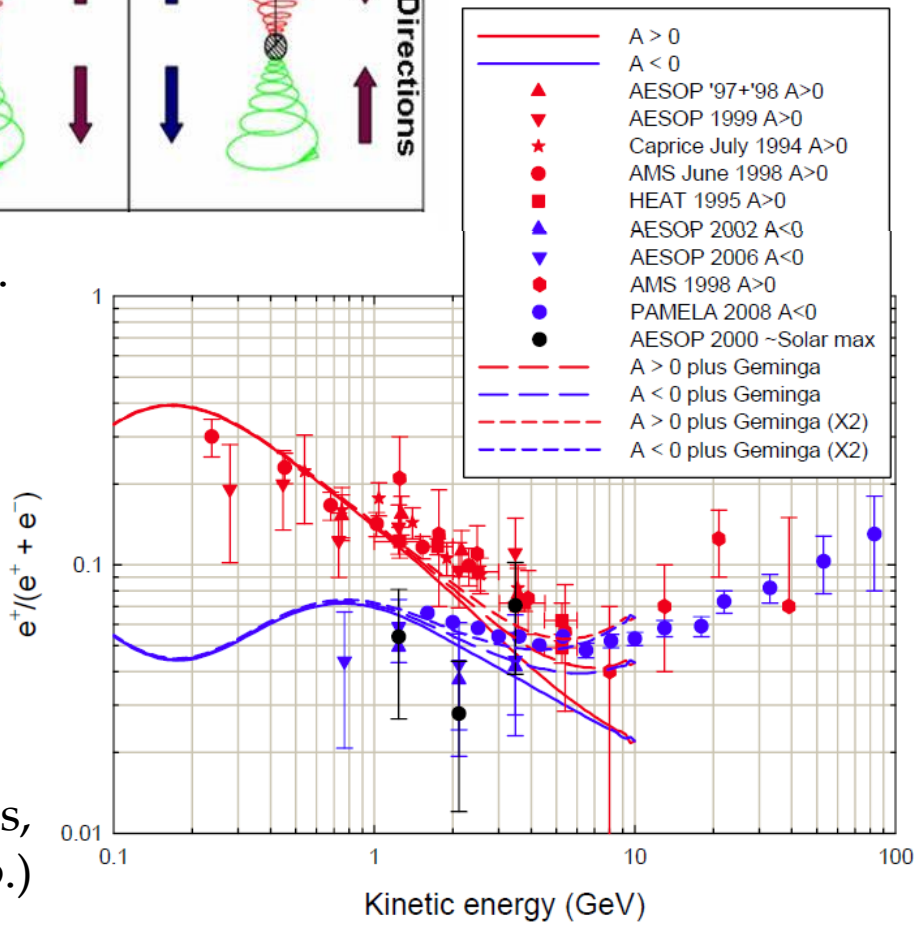
Charge Sign Dependent Solar Modulation

Reversals of the solar magnetic field occurs every 11 years.





Clem et al.



Burger, Bieber, Clem, Matthaeus,
Pei, Stanev, Yuksel (in prep.)

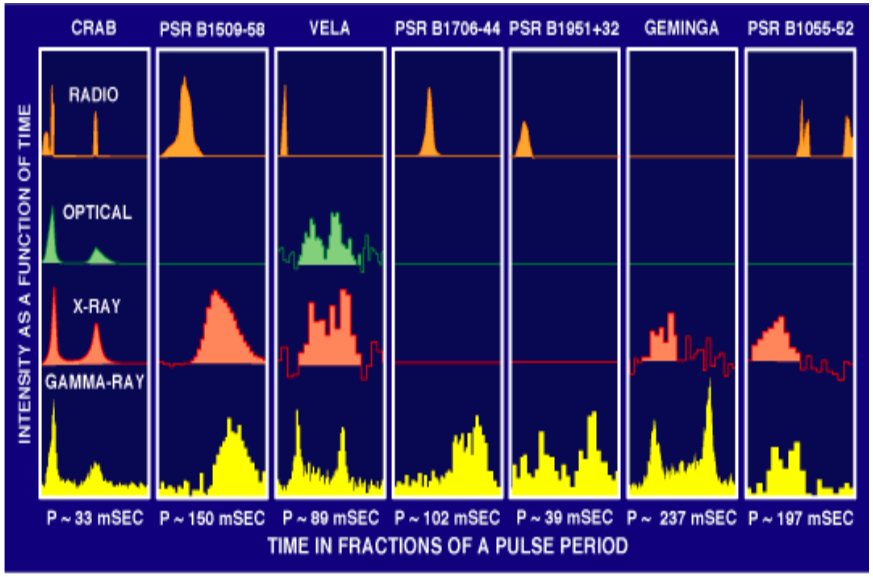
Geminga:

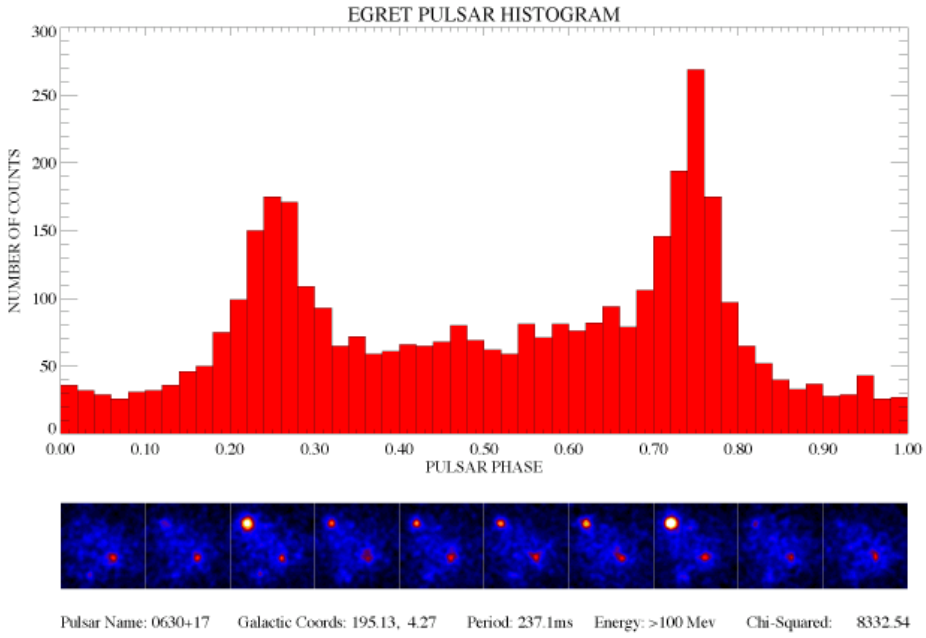
- Radio quite
- First pulsar to be discovered through gamma rays
- Until recently, no evidence of a high energy activity beyond immediate neighborhood

$$r_G \sim 250^{+120}_{-62}\ \mathrm{pc}$$

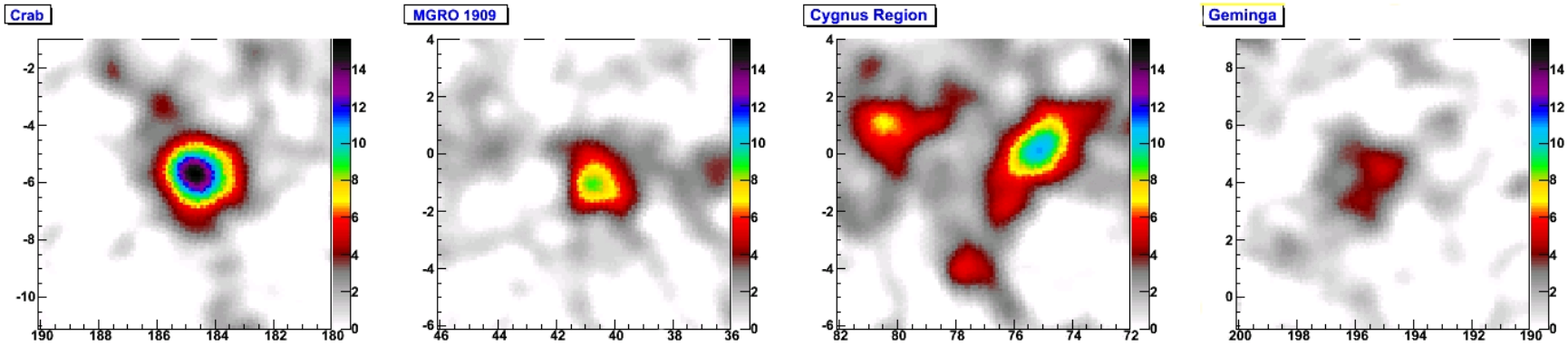
$$t_G \sim 3 \times 10^5\ \mathrm{yr}$$

- Displacement of up to ~100 pc since its birth is possible





Milagro Galactic Plane Survey

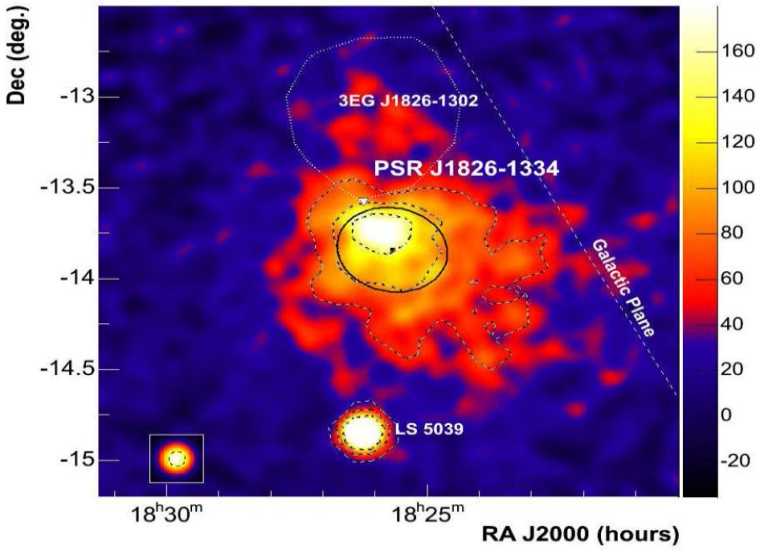


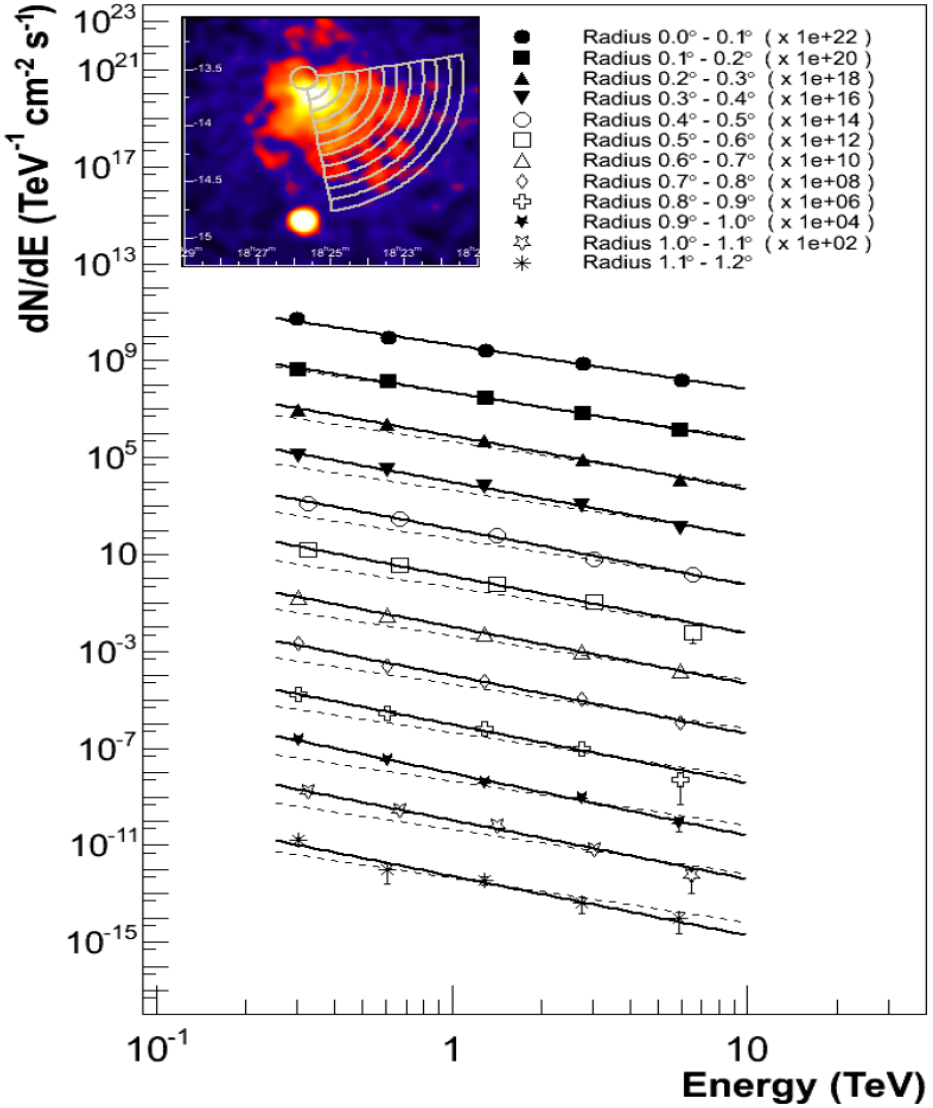
Object	Location (l, b)	Flux[c] at 20 TeV $\times 10^{-15}$ $TeV^{-1}cm^{-2}s^{-1}$	Extent Diameter (deg)
Crab	184.5, −5.7	10.9 ± 1.2	-
MGRO J2019+37	75.0, 0.2	8.7 ± 1.4	$1.1^{\circ} \pm 0.5^{\circ}$ [d]
MGRO J1908+06	40.4, −1.0	8.8 ± 2.4	$< 2.6^{\circ}\,(90\%CL)$
MGRO J2031+41	80.3, 1.1	9.8 ± 2.9	$3.0^{\circ} \pm 0.9^{\circ}$
C1	77.5, −3.9	3.1 ± 0.6	$< 2.0^{\circ}\,(90\%CL)$
C2	76.1, −1.7	3.4 ± 0.8	[e]
C3	195.7, 4.1	6.9 ± 1.6	$2.8^{\circ} \pm 0.8^{\circ}$
C4	105.8, 2.0	4.0 ± 1.3	$3.4^{\circ} \pm 1.7^{\circ}$

- Milagro detection puts Geminga among growing class of TeV PWNe
- Detection of TeV gamma rays indicates the existence of a nearby cosmic ray accelerator:
  - If gamma rays have a leptonic origin, the source is young & close enough to make a significant contribution to CR electrons & positrons
- We can go beyond simply assuming pulsar's are responsible for the observed positron/electron excess

More Distant PWN by HESS

HESS J1825-137, Aharonian et al.



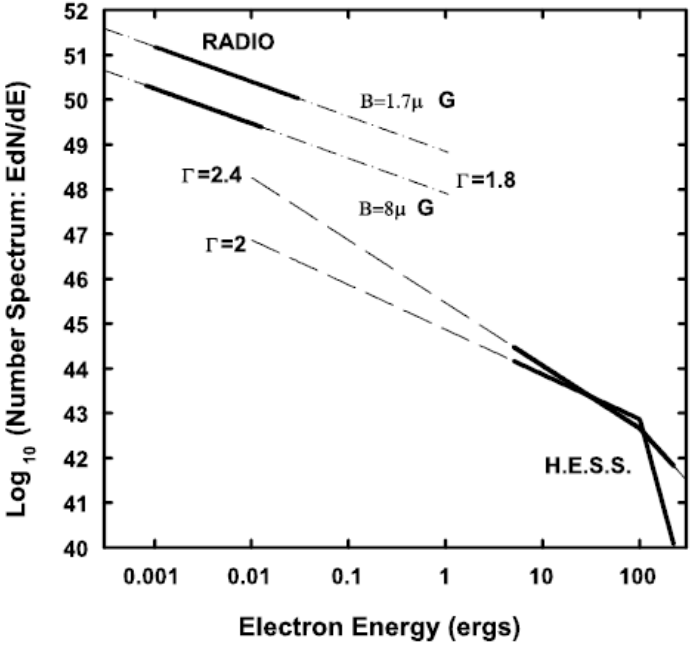


A Generic Leptonic Model

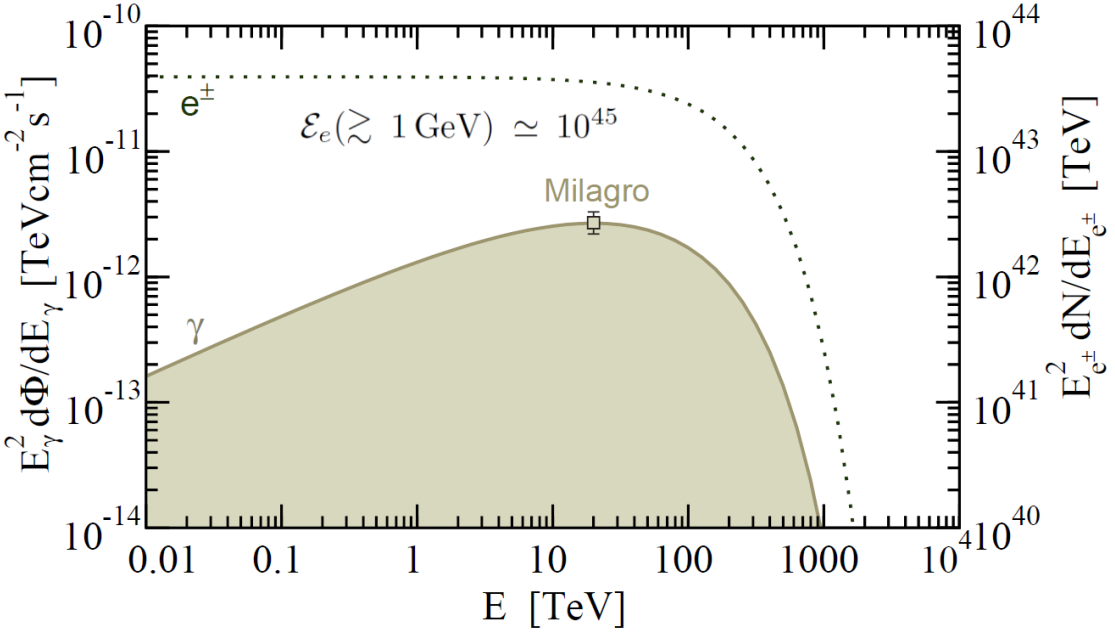
$$\gamma_{max} = E_{max}/(m_e c^2)$$
$$dN/d\gamma = N_0 \gamma^{-\alpha} e^{-\gamma/\gamma_{max}}$$
$$E_{min} = 1 \text{ GeV}, E_{max} = 200 \text{ TeV}$$

- The age of Geminga is already much larger than the IC cooling time on CMB photons of the > 100 TeV electrons needed to produce > 20 TeV gamma rays --> Fresh Pair Production

$$\alpha = 2$$

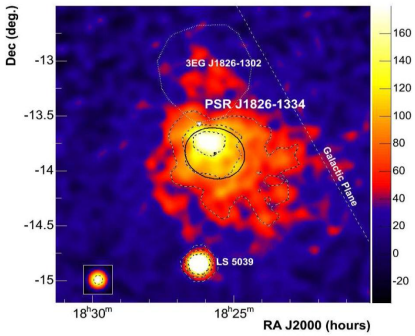


De Jager

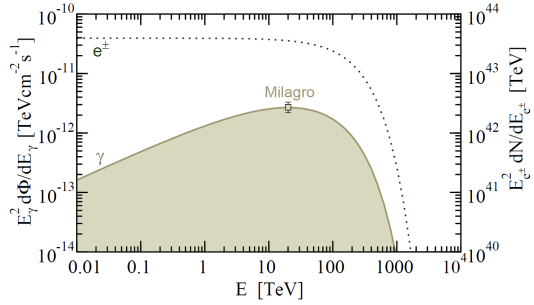


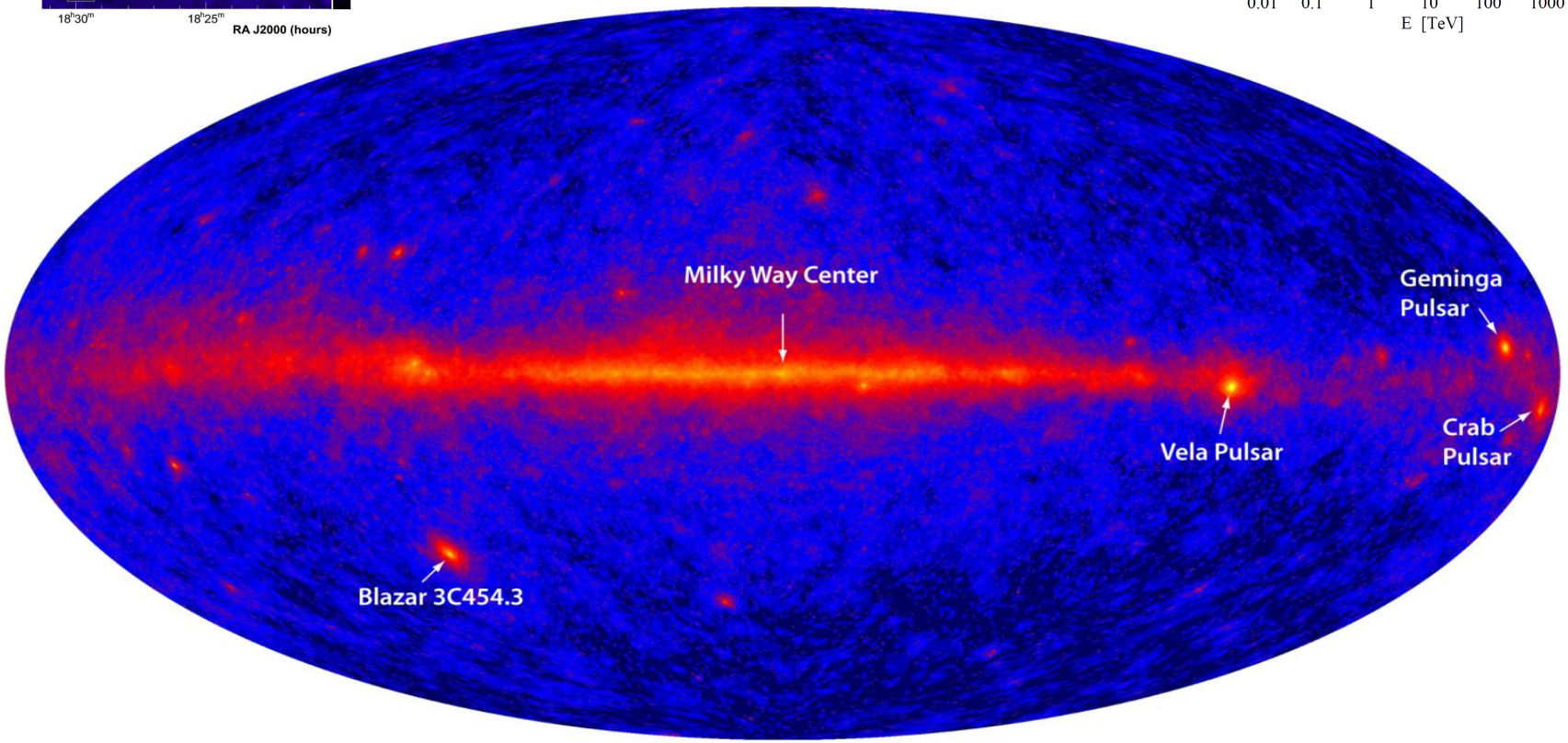
Yuksel, Kistler, Stanev

Future Prospects



More observations will be needed to pin-down the total energy and how it is distributed both in energy and spatially.



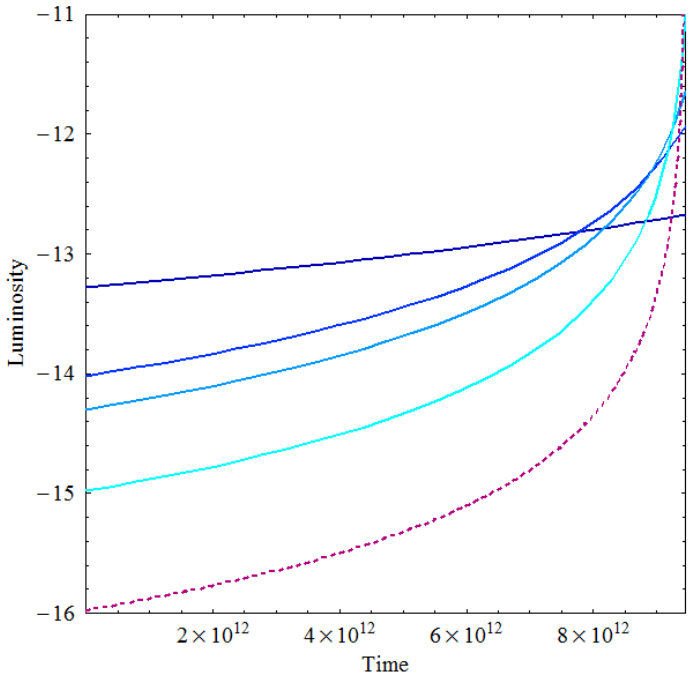


Local Positrons from a Nearby Continuously Emitting Source

Assuming breaking via magnetic dipole radiation:
Pulsar spin down luminosity evolves as $\propto (1+t/t_0)^{-\frac{n+1}{n-1}}$

The injection rate of relativistic e-e+ by Geminga:

$$\mathcal{L}_e(t) = \frac{\mathcal{E}_G}{t_G} \frac{(1+(t_G-t)/t_0)^{-2}}{\int^{t_G} dt'(1+(t_G-t')/t_0)^{-2}}$$



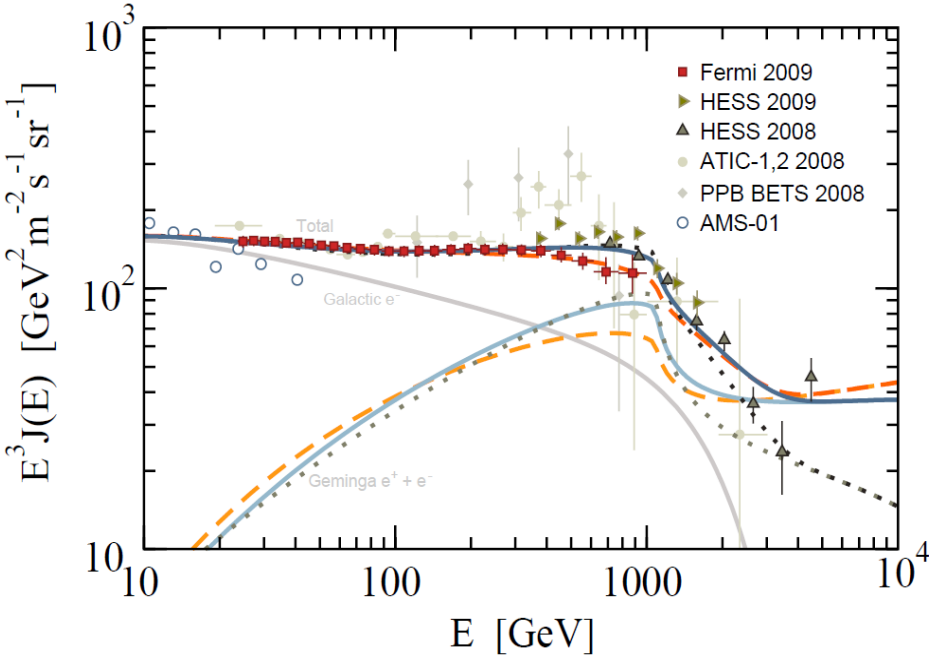
Geminga was much stronger in the past and dominated the TeV sky: Multi-GeV positrons may still be reaching us today

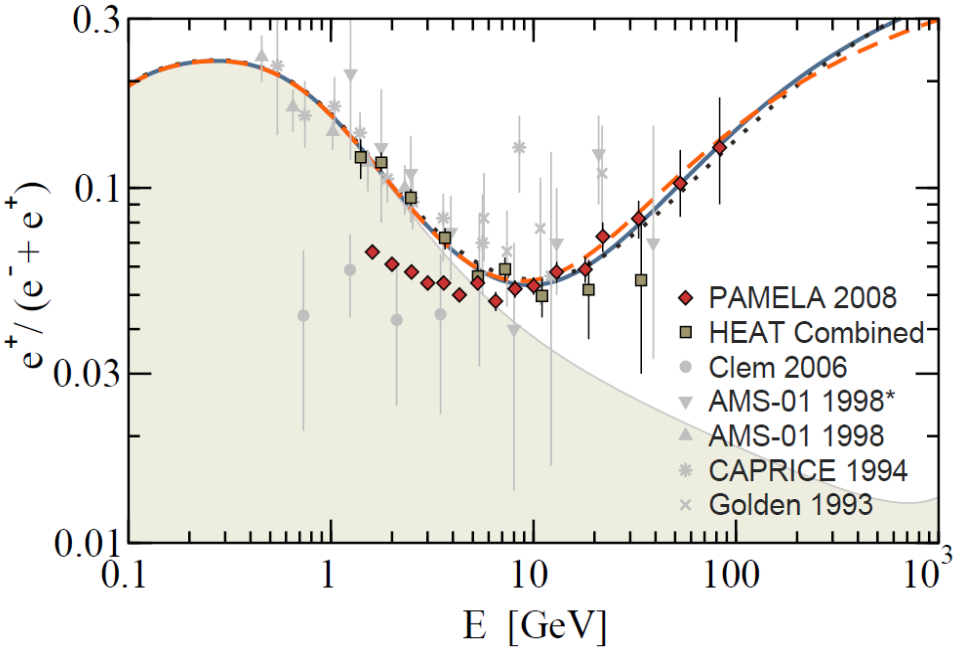
Possible Geminga Contributions

Dotted, Solid, Dashed lines correspond to $t_G = 3 \times 10^5$ yr

$\mathcal{E}_G = 1, 2, 3 \times 10^{48}$ erg $\quad \delta = 0.4, 0.5, 0.6$

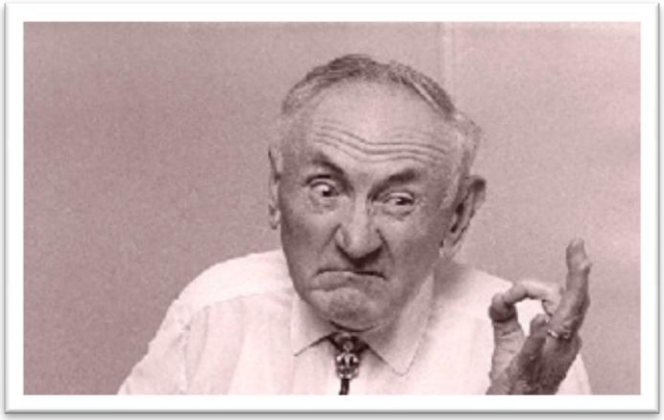
$r_G = 150 \rightarrow 250$ pc, 220 pc, 250 $\rightarrow$ 200 pc





Yuksel, Kistler, Stanev

What about Dark Matter?



- What to look for:
  - Annihilating dark matter
  - Decaying dark matter
- Where to look at:
  - γ-rays from Galactic Center, Galactic Halo, Dwarf Satellites, Nearby Galaxies, Cosmic sources
  - ν's from the Sun, Galactic Halo
  - Anti-particle spectrum measured in solar neighborhood

$$\chi\chi \rightarrow e^+e^-$$

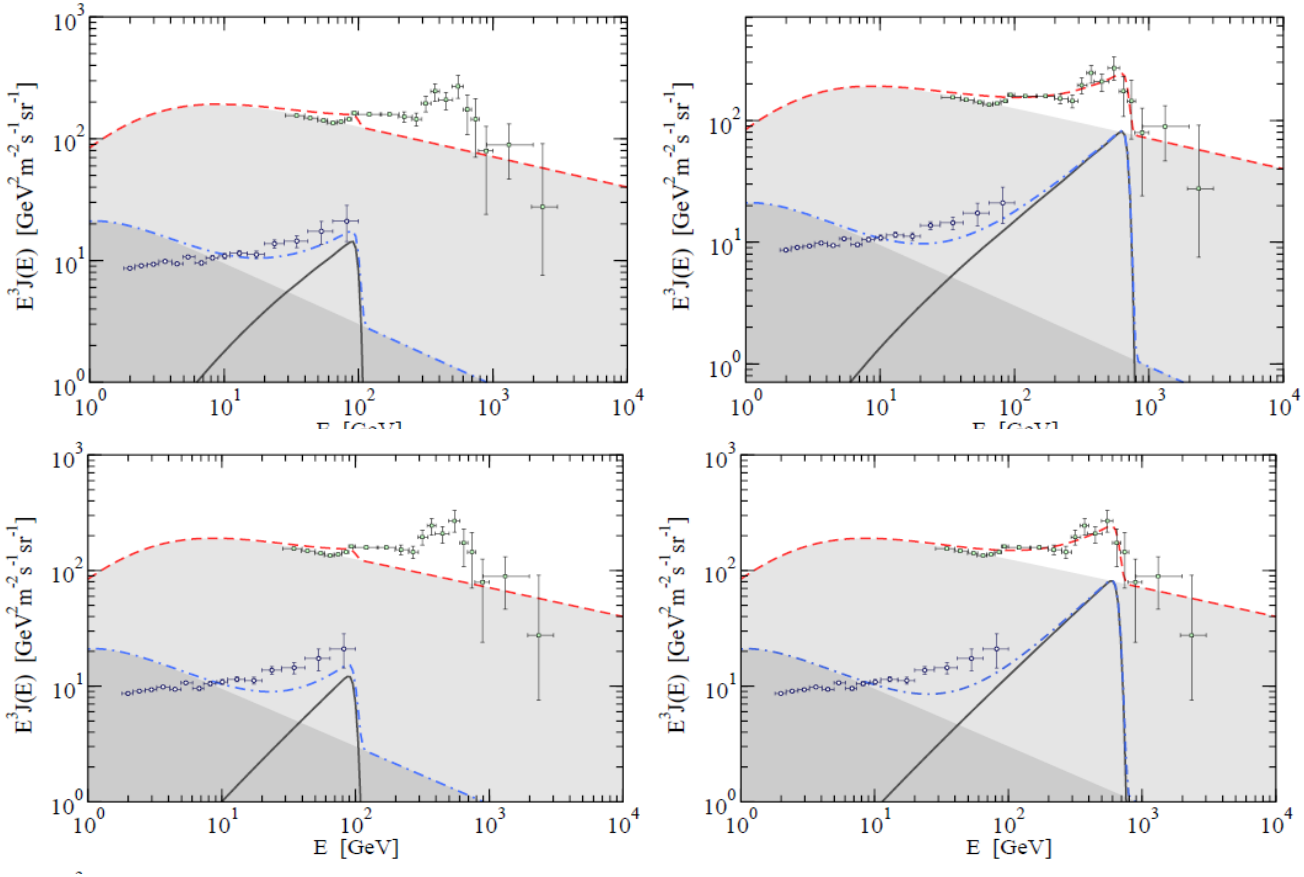
$m_\chi \sim 0.1\text{–}0.7\ \text{TeV}$

$f_B\langle\sigma v\rangle \sim 10^{-24}\ \text{cm}^3/\text{s}$

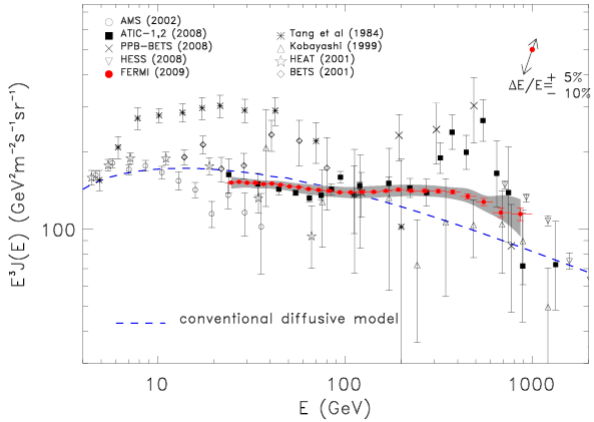
$$\chi \rightarrow e^+e^-\nu$$

$m_\chi \sim 0.3\text{–}2\ \text{TeV}$

$\tau \sim 10^{27}\ \text{s}$



Gogoladze, Khalid, Shafi, Yuksel



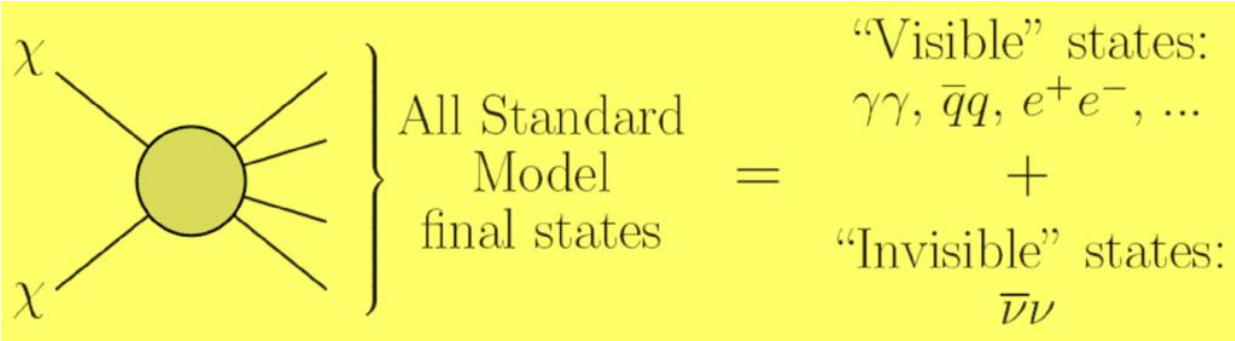
Fermi favors: $\langle\sigma v\rangle \sim 10^{-23}\ \text{cm}^3/\text{s}$

$\chi\chi \rightarrow \mu^-\mu^+ \rightarrow e^-e^+ +$ (Neutrinos)

Model Independent Limit on DM Annihilation Cross Section

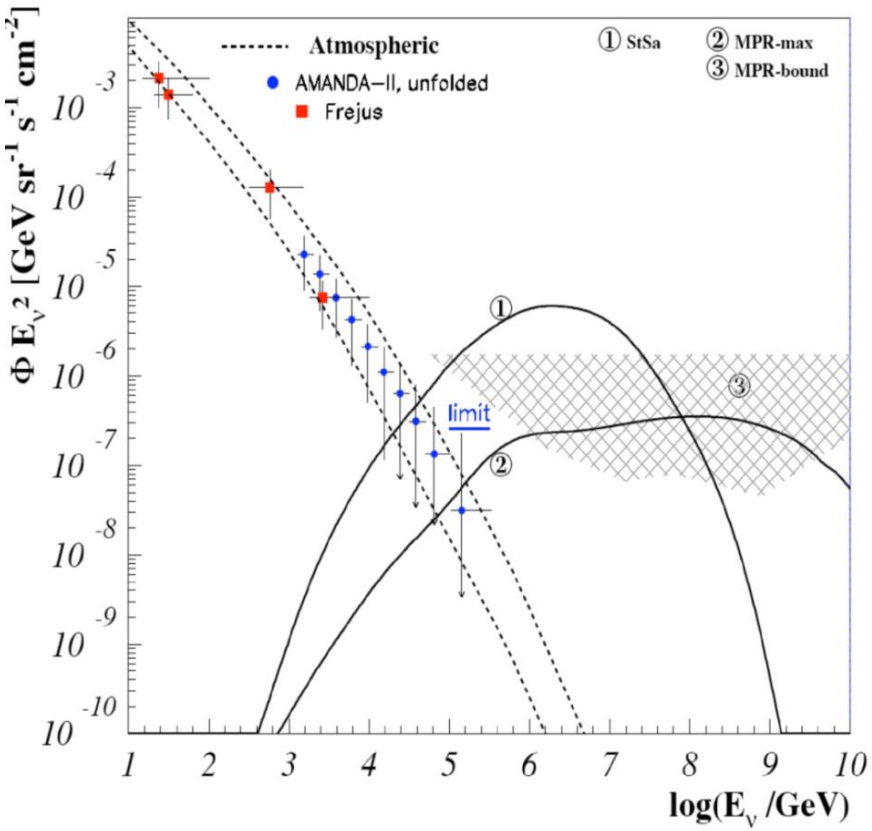
- Assume DM annihilations only produce Standard Model final states

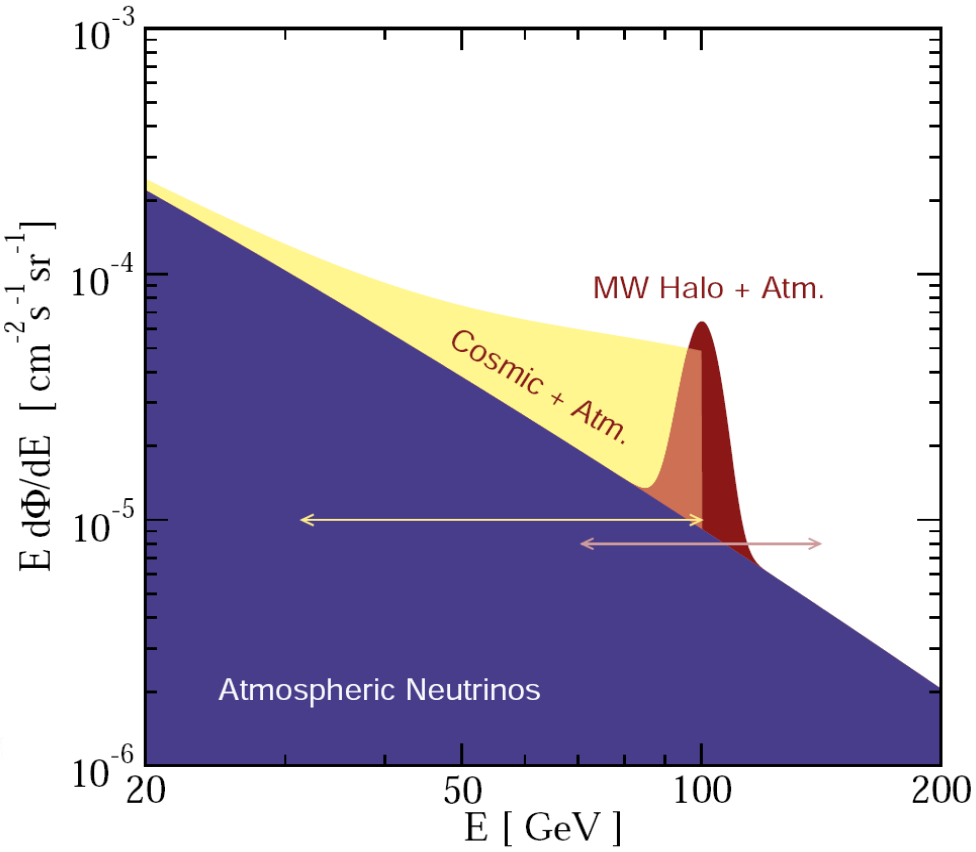
- Stringent upper limit on total annihilation cross section can be obtained by assuming only neutrinos are produced in final states (worst case, least visible)



- Anything else will eventually produce much more visible gamma rays (leading to a stronger limit)

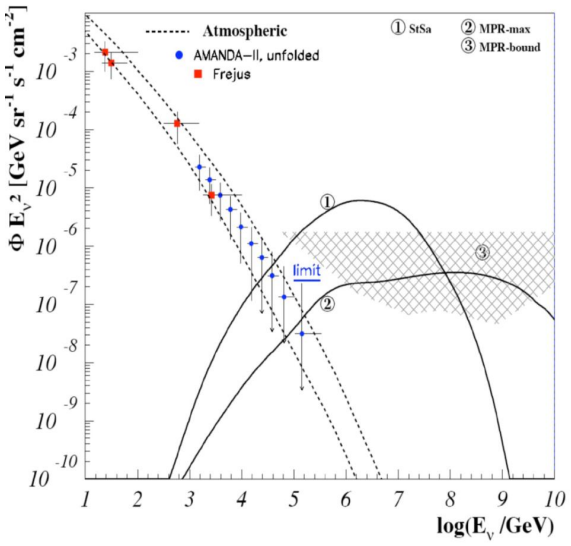
Compare to Atmospheric Nu Flux



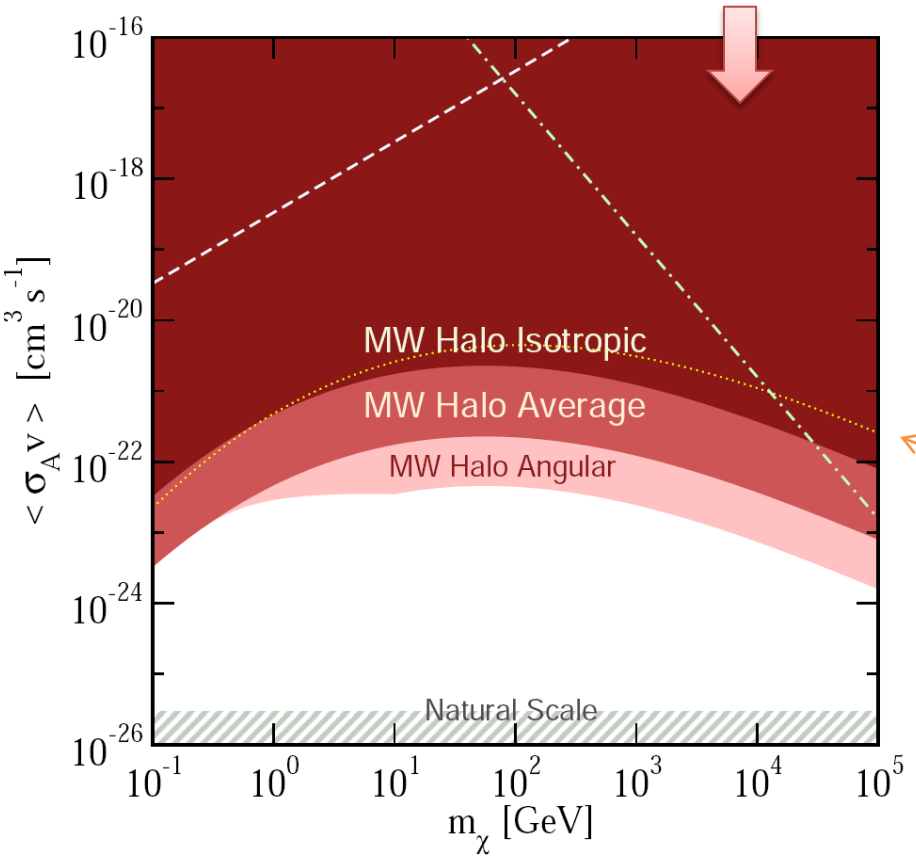


Yuksel, Horiuchi, Beacom, Ando

Limits on <σv> from ν Flux



"Even Neutrinos are overproduced"



Cosmic nu:
Beacom,
Bell, Mack

Milky Way Halo: Yuksel, Horiuchi, Beacom, Ando